

Ballistic Research Laboratories

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BALLISTIC LABORATORY



REPORT

REPORT ON INVESTIGATION OF THE CAUSES UNDERLYING ERRATIC POWDER PRESSURES OBTAINED FROM CRUSHER GAUGES

(IN CONNECTION WITH PROJECT RB 116)
(O.O. 413.6/12432 - APG 413.6/487)

BY

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ABERDEEN PROVING GROUND
ABERDEEN, MD.

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ABERDEEN PROVING GROUND, MD.,
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REPORT ON INVESTIGATION OF THE CAUSES UNDERLYING ERRATIC
POWDER PRESSURES OBTAINED FROM CRUSHER GAUGES

{IN CONNECTION WITH PROJECT RB 116}
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OBJECT OF TEST

To obtain comparative data regarding the behavior of crusher gauges, assembled under different conditions and with different tolerances, from controlled firings in the 3" A.A. Gun Liner M3, No. 138, chromium plated.

DISCUSSION

OCM Item 12462 directed certain tests to be performed on 3" A.A. Gun Liner M3, #138, which was chromium plated in the bore at the Naval Gun Factory, Washington Navy Yard. This test provided for proof firing to be followed by 50 rounds in 5-round series, with taking of periodic bore measurements and bore impressions. The results of this test, insofar as effect on the liner is concerned, are reported in Firing Record 8807, (O.P. 4987; O.O. 472.93/4449; A.P.G. 472.91/362), and in First Partial Report on test of 3" A.A. Gun Liner M3, No. 138, chromium plated, and Fifth Report on O.P. No. 4987, Ordnance Program 4987, OCM Item 12462, dated February 12, 1936.

The Proving Ground has experienced erratic results in powder pressure readings obtained from crusher gauges for some time. Prior to the adoption of the new standard firing record forms, which provide for recording individual pressures obtained as well as mean pressures, these erratic results were not so apparent. The old firing record forms reported the mean pressures only, and wide variance in individual readings were often

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FIRING RECORD FILE

MAR 17 1936

absorbed in the mean result. In cases where standard firings were made under these conditions of pressure taking or where established charge-pressure curves for a lot of powder were used to obtain data for firings, and the firings made from the curves gave contrary results, the effects of erratic individual pressures were forcefully brought to view.

The cannon crusher gauges in use today are of the Noble type, an outgrowth of the Rodman knife gauge. Those used at the Aberdeen Proving Ground have been in service for many years, many having been formerly used at Sandy Hook Proving Ground. The specifications for these gauges provide for pistons to be made of hardened tool steel, ground to size and the gauge bodies to be made of forged No. 3 steel. This latter steel corresponds to W.D. 1055, a medium carbon steel. In the absence of specified physical requirements and heat treatment of the bodies and pistons, it can be seen that there should be great variance in their ability to withstand scoring, distortion and permanent deformation. The clearance between the piston and the body is 0.0002" with tolerances of +.004" in cylinder diameter, and -.0004" in piston diameter.

The regulations at the Proving Ground provide for the selection of cannon pressure gauges for standardization firings having clearances of .0002" between piston and cylinder with tolerances of +.0002" on the cylinder diameter and -.0002" on the piston diameter. For other than standardization firings the clearance is .0002" between piston and cylinder, with tolerances of +.0004" on cylinder diameter and -.0004" on piston diameter.

Mr. R. H. Kent in a paper entitled "Report on Some Sources of Error in Piezo-electric and Crusher Gauge Measurements (In Connection with Project RB 117)", dated Aberdeen Proving Ground, Dec. 2, 1935, concludes that the pinching effect observed in the case of the piezo-electric gauges should also affect the measurements made with the copper crusher gauges. This pinching effect is caused by the pressure of the powder gases applied to the exterior cylindrical surface of the gauge body, distorting the inner cylinder wall and binding the piston, so as to prohibit free movement.

From all of the foregoing it was concluded that the firings to be conducted in the 3" A.A. Gun Liner M3, No. 138, presented an excellent opportunity to schedule some tests of crusher gauges in which their behavior under certain variables of assembly and selection could be observed.

In O.O. 471.91/2052; A.P.G. 472.91/362-2, the Ordnance Office authorized tests to be conducted in this gun along the following lines:

(a) Select 16 medium caliber crusher gauges which are in good condition, assemble pistons to 8 of these gauges to give total clearance in each case of .0005" between cylinder wall and piston. Assemble pistons to the other 8 crusher gauges to give a total clearance of .0010" between cylinder wall and piston.

(b) Assemble all gauges with the cylinder wall and piston wiped dry, no lubricant to be used about the gauges except on closing cap threads and body washer.

(c) All gauges to be assembled, disassembled, measured, etc., by the Gauge Section, using the same procedure at all times.

(d) Copper cylinders to be of the same lot and anneal with zero initial compression.

(e) Four gauges of each lot of 8 described in (a) above, to be assembled with standard copper obturator cups, the remaining gauges to have the copper cup replaced with a wax seal consisting of 2 parts cup grease, 2 parts beeswax and 1 part resin.

(f) The 16 gauges will be divided into four sets of four gauges each, each set to consist of:

1 gauge - .0005" clearance; copper cup
1 gauge - .0005" clearance; wax obturator
1 gauge - .0010" clearance; copper cup
1 gauge - .0010" clearance; wax obturator

These gauges are all numbered and sets will remain intact throughout the whole test.

(g) Forty rounds to be fired at five different pressures:

8 at 20,000 lbs. per sq. in.
8 at 27,000 " " " "
8 at 31,500 " " " "
8 at 36,000 " " " "
8 at 41,200 " " " "

(h) Each round to have a set of four gauges, assembled as described in (f) above, inserted in the case.

(i) In half of the rounds at each pressure, the set of gauges is to be fixed in the bottom of the case. In the other half of the rounds, the gauges are to be placed in the case in accordance with current procedure at the Proving Ground.

Procedure

A lot of powder was selected from that available at the Proving Ground for use in this test. The powder selected was DuPont 1492 - 1918 - for 6" Gun M1900-03-05. It is a pyro powder, multiperforated grain having a web thickness of 0.0360". This powder is suitable for use in the 3" A.A. Gun M3.

Standard 3" cast iron proof slugs, weighing 15 lbs. each, were used in all firings. Cartridge cases, 3" A.A. Mk. II Al, drawing 71-5-3, unmodified, were used with M21 Primers, Lot 1355-15, in all rounds.

Firings were conducted in groups of five rounds each, the first round of each group being a warming round, the remaining four having gauges assembled as prescribed. This was necessary due to the limited number of gauges used, 16 in all or sufficient for 4 rounds, and the requirements of the original directive (OCM Item 12462) which called for five-round groups between stargauging, etc. Two groups were fired at each pressure, each group being fired on a different day usually since the gauges had to be disassembled and reassembled by the Gauge Section between groups and the necessary stargauging of the liner performed. Boulenge muzzle velocities were taken on all rounds.

The description of assembly of each group of five rounds follows:

<u>Round</u>	<u>Fixed or Loose in Case</u>	<u>Gauge No.</u>	<u>Piston Clearance</u>	<u>Obturator Seal</u>
Warming	-	No gauges	-	
1	Fixed	5942	.0010	Wax
		4525	.0010	Copper
		4734	.0005	Wax
		4190	.0005	Copper
2	Fixed	4970	.0010	Wax
		2422	.0010	Copper
		4748	.0005	Wax
		2834	.0005	Copper
3	Loose	5908	.0010	Wax
		3640	.0010	Copper
		4744	.0005	Wax
		4329	.0005	Copper
4	Loose	4774	.0010	Wax
		1728	.0010	Copper
		4875	.0005	Wax
		3259	.0005	Copper

The problem of fixing the four gauges in rounds 1 and 2 of each series presented difficulties. Various metal holders were devised and tried out in an effort to hold the four gauges upright in the case and against the case wall in order that there would be no interference with the action of the primer. The MII A1 case is rather long, and the mouth opening is only 3" in diameter. With the facilities available at the Proving Ground there appeared to be no simple and inexpensive method of accomplishing this. The Research Division at the Proving Ground suggested that the four gauges be held together with strong rubber bands, each gauge in contact with the primer body and resting on the bottom of the inside of the case. It was believed that no interference with the primer action would occur. A simple fixture was devised for assembling the gauges in position in this manner, and this method was used for fixing the gauges in rounds 1 and 2 of each series.

The data obtained in the firings are shown on the attached sheets, Exhibits "A" to "F". The data shown on Exhibit "F" was obtained by firing 2 additional groups using a powder charge to give pressures lower than those used for the initial test shown on Exhibit "A". This was done to obtain additional data in the lower pressure range and to see if the high pressures shown on Exhibit "E" had permanently affected the gauges.

Pressures obtained were not corrected in any way for erosion, etc.

Analysis of Data

Exhibit "A"

It will be noted that the results obtained in the firings of the first series, Rounds 14, 15, 16 and 17, showed very little difference between gauges with different characteristics. When these firings were repeated three days later (Rounds 19, 20, 21 and 22) under as near identical conditions as possible, it is noted that the gauges having pistons with .0005" clearance and wax obturators in Rounds 19, 20 and 22, showed considerable dispersion from the other gauges assembled with them in the rounds.

The dispersions from the mean values for all combinations of variables as shown in columns 13 to 16, inclusive, indicate that the gauges having large piston clearance (.0010") and assembled with copper cup obturators show very much less dispersion in pressure than any other combination tested.

Attention is invited to gauge No. 4744 assembled in the 3rd round of each series. This gauge has a piston with

.0005" clearance and was always assembled with a wax obturator. Its behavior, however, is unlike that of other gauges with similar characteristics, and the results obtained from it are more like those obtained with the .0010" clearance gauges. This gauge was carefully checked and rechecked several times to find out the cause for this paradoxical behavior. No explanation is offered.

Exhibit "B"

The results shown for these series continue to follow the trend indicated in Exhibit "A". The mean dispersions are of greater magnitude due to the greater effect of the low reading gauges. The dispersion in columns 11 and 12 indicate that fixing the gauges in the round is not an advantage, but contributes to greater deviations.

Gauge No. 4744 continues to behave at variance with similar gauges. Gauges having large piston clearance and copper obturator cups have the least dispersion.

Exhibit "C"

The results of previous firings are unchanged by these series. Through a misunderstanding one gauge in each series, Rounds 35 and 42 were assembled with copper cups instead of wax. This change was considered in arriving at the mean values.

Exhibits "D" and "E"

The results of these firings are consistent with previous results.

Exhibit "F"

These series were fired to see what effect, if any, the repeated firings had on the gauges.

It was expected that the results would be consistent with those shown on Exhibit "A". Such was not the case, and it appears that some of the gauges have been permanently deformed, or otherwise changed so that they no longer behave normally.

CONCLUSIONS

From the data obtained in these tests it appears that gauges with tight pistons will give consistently lower pressures and greater dispersions than will be given by gauges having pistons with greater clearance.

That these tests do not give sufficient data on which to base the limits of clearance between pistons and cylinders in gauges.

That definite conclusions cannot be drawn from this data regarding the effects of fixation of gauges, or use of wax compounds in lieu of copper obturator cups; due to the confusing effects of the variables introduced into the tests.

RECOMMENDATIONS

That further tests be made to determine the maximum piston clearance which can be allowed.

That no further tests be made at this time having reference to fixation of gauges in the round.

That further investigation of lubrication of the gauge parts be conducted.

That the search for a substitute for copper obturating cups be continued.

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RECAPITULATION - PRESSURE DATA- SPECIAL GAUGES IN 3" A.A. GUN, M3, WITH CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (MED CAL); 4 PER ROUND, ALL ASSEMBLING, MEASURING ETC BY GAUGE SECTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ. IN.	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ. IN. (OTS mic spindle)	MEAN OF GAUGES WITH 0.0010" PISTON CL.	MEAN OF GAUGES WITH 0.0010" PISTON CL.	MEAN OF GAUGES WITH copper obt. cups	MEAN OF GAUGES WITH wax obturators	MEAN OF GAUGES ASSEMBLED TO ROUND	INDIV MEAN DISPERSION PRESSURE	MAX DISPERSION GAUGES FIXED IN ROUND	MAX DISPERSION GAUGES LOOSE IN ROUND	INDIV DISPERSION 0.0003" PISTON CLEARANCE	INDIV DISPERSION 0.0010" PISTON CLEARANCE	INDIV DISPERSION COPPER OBT. CUPS	INDIV DISPERSION WAX OBT.	FIRING DATE	REMARKS	
2	14	20,000	5942	19,550	19,125	19,275	19,150	19,250	19,200	+350 -200 -250 +100	600			+275 -275	-150 -300	+300	FIRED JAN 10, 1936 A.M.	Very consistent	
3			4525	19,000															
4		3#203 K1492	4734	18,950															
5			4190	19,300															
6	15	P490 POWDER	4970	18,900	19,000	19,000	18,875	18,975	18,925	-25 +175 +125 -275	450			-100 +100	-225 +225	-75		Very consistent	
7			2422	19,100															
8			4748	19,050															
9			2834	18,650															
10	16		5908	19,550	19,150	19,600	19,075	19,375	19,375	+175 +275 -175 -275		550		-50 +50	+275 -275	+175		Very consistent	
11			3640	19,650															
12			4744	19,200															
13			4329	19,100															
14	17		4774	19,240	19,270	19,270	19,875	19,195	19,510	-270 -10 -360 +640		1000		+120 -120	-325 -325	+75		TIGHT PISTON - WAX - low pressure GREATEST DISP - TIGHT PISTON, COPPER CUP	
15			1728	19,500															
16			4875	19,150															
17			3259	20,150															
18	19	20,000	5942	18,975	19,275	19,040	19,250	17,065	18,150	+825 +950 -3000 +1350	4,250			-60 +60	-150 +150	+190	FIRED JAN 12, 1936 P.M.	TIGHT PISTON, WAX - low pressure	
19			4525	19,100															
20			4734	15,150															
21			4190	19,400															
22	20		4970	19,000	19,000	19,000	18,675	16,350	17,460	+1540 +1540 -3960 +890	5,500			0 0	+325 -325	+1750		TIGHT PISTON WAX - low pressure	
23			2422	19,000															
24			4748	13,500															
25			2834	18,350															
26	21		5908	19,400	19,350	19,200	19,200	18,425	18,825	+575 +375 -1375 +425		1950		+100 -100	-30 -975	+975		TIGHT PISTON, WAX - low pressure	
27			3640	19,200															
28			4744	17,450															
29			4329	19,250															
30	22		4774	19,025	19,090	19,090	19,450	15,915	17,680	+1345 +1470 -1880 +2070		6950		-65 +65	-344 -344	+3115		TIGHT PISTON, WAX - low pressure	
31			1728	19,150															
32			4875	12,800															
33			3259	19,750															
34	MEAN VALUES	20000		18640	18,075	19,210	19,230	18,060	18,640	—	2,700	2,610	2,460	197	445	2340		EXHIBIT "A"	

②

RECAPITULATION PRESSURE DATA - SPECIAL GAUGES IN 2" MAGNUM 192 CHROMIUM PLATED RIFLE #132

SELECTED PRESSURE GAUGES (MEAS.) - 4 per round, 150 rounds, measuring R.F. by GAUGE 26-7001

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18						
SERIAL NUMBER OF ROUND	EXPIRES PRESSURE #15.14	MEDIUM CALIBER GAUGE NO.	PRESSURE M/SQ IN (.075" MICK SPINDLE)	MEAN OF GAUGES WITH 0.0005" PISTON CL	MEAN OF GAUGES WITH 0.0010" PISTON CL	MEAN OF GAUGES WITH COOPER 0.0125"	MEAN OF GAUGES WITH WAX OBSTURATOR	MEAN OF ALL GAUGES ASSEMBLED TO ROUND	INDIV. MEAN DISPERSION PRESSURE	MAX. DISPERSION GAUGES FIXED IN ROUND	MAX. DISPERSION GAUGES LOOSE IN ROUND	INDIV DISPERSION WITH 0.0010" PISTON CLEARANCE	INDIV DISPERSION WITH 0.0010" PISTON CLEARANCE	INDIV DISPERSION COOPER 0.0125" CUPS.	INDIV DISPERSION WAX OBSTURATOR	FIRING DATE	REMARKS						
2	34	31.500	5442	29,500	30,200	30,900	23,650	27,275	+2,225	13,100				-700	+5,850	1							
3			4525	30,900														+3,625			+700	0	
4		(45.14) PYRO	4704	17,800														-9,415					
5		(1492) GAUGE	4190	30,900														+2,625					
6	35		4970	28,275	29,410	30,275	28,275	25,670	+2,605	17,150				-1,140	0	17,1936 P.M.	This gauge assembled with copper cup						
7			2422	30,550														+4,880			+1,140	+5,750	
8			4748	13,400														-12,270					
9			2834	30,450														+4,780					
10	36		5908	30,225	30,910	31,300	28,360	29,830	+395	5,100				-690	+1,860	JAN 17, 1936 P.M.							
11			3640	31,600														+1,770			+690	+300	
12			4744	26,500														-3,220					
13			4329	31,000														+1,170					
14	37		4774	27,900	29,450	22,150	20,900	21,525	+6,375	17,200				-1,550	+7,000	JAN 21, 1936 A.M.							
15			1728	31,000														+9,475			+1,550	+8,850	
16			4875	13,900														-7,625					
17			3259	13,300														-8,225					
18	39	31.500	5942	30,350	30,700	31,000	24,115	27,590	+2,760	13,050				+350	+4,175	JAN 21, 1936 A.M.							
19			4525	31,050														+3,760			-350	+50	
20			4704	18,000														-9,590					
21			4190	30,950														+2,360					
22	40		4970	28,200	29,050	29,625	22,450	26,040	+2,160	13,200				-850	+2,750	JAN 21, 1936 A.M.							
23			2422	29,900														+3,860			+850	+275	
24			4748	16,700														-9,340					
25			2834	29,350														+3,310					
26	41		5908	30,100	29,075	28,125	28,325	28,220	+1,880	3,550				+1,025	+1,775	JAN 21, 1936 A.M.							
27			3640	28,050														-170					
28			4744	26,550														-1,670					
29			4329	28,200														-20					
30	42		4774	29,900	30,050	29,900	25,610	25,610	+4,290	4,700				-150	0	JAN 21, 1936 A.M.	This gauge assembled with copper cup						
31			1728	30,200														+4,590			+150		
32			4875	15,500														-10,110					
33			3259	26,850														+1,240					
40	MEAN VALUES			26,470	23,085	29,860	28,850	24,640	26,470	14,125	10,265	4,490	800	1590	4,735								
* NOT CONSIDERED IN AVERAGES IN ROUNDS 34-35 * MEAN OF 6 VALUES ONLY																							
EXHIBIT "C"																							

EXHIBIT "C"

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A.A. JOURNAL'S CHROMIUM PLATED LINER #132

SELECTED PRESSURE GAUGES (MEDICAL); 4 per round, All ascending increasing etc by Gauge Serial No.

1	2	3	4	MEAN OF GAUGES WITH				9	10	11	12	INDIVIDUAL DISPERSION WITH				17	18
				0.0005" PISTON CL	0.0010" PISTON CL	COPPER CUPS	WAX OBTURATOR					0.0005" PISTON CL	0.0010" PISTON CL	COPPER CUPS	WAX OBT		
SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ IN	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ IN (0.75" MICR SPINDLE)					MEAN OF ALL GAUGES IN ROUND	INDIV MEAN DISPERSION PRESSURE	MAX. DISPERSION GAUGES FIXED	MAX. DISPERSION GAUGES LOOSE					DATE OF FIRING	REMARKS
2	49	36,000	5942	34,000	29,890	33,975	27,400	31,930	+2,070	18,175							
3			4525	33,950													
4		4912	4734	20,800													
5		4912	4190	38,975													
6	50	36,000	4970	34,300	28,060	35,675	27,410	31,870	+2,430	16,525							
7			2422	37,050													
8			4748	20,525													
9			2834	35,600													
10	51		5908	34,675	36,190	36,390	34,120	36,300	+1,800		5,175						
11			3640	38,100													
12			4744	33,600													
13			4329	38,775													
14	52		4774	29,450	26,960	33,400	22,200	29,700	-250		22,400						
15			1728	37,350													
16			4875	14,950													
17			3259	36,975													
18	54	36,000	5942	39,550	32,650	40,350	21,075	36,500	+3,050	20,100							
19			4525	41,150													
20			4734	22,600													
21			4190	42,700													
22	55		4970	38,100	30,000	38,600	30,350	34,300	+3,800	16,500							
23			2422	39,100													
24			4748	22,600													
25			2834	37,400													
26	56		5908	40,800	38,850	39,470	31,700	39,150	+1,650	26,75							
27			3640	38,125													
28			4744	38,600													
29			4329	39,100													
30	57		4774	30,900	25,100	34,850	25,950	29,975	+925	17,800							
31			1728	38,800													
32			4875	21,000													
33			3259	29,200													
34																	
35		36,000		33,700	30,960	36,600	37,645	29,800	33,745	17,825	12,000	6,400	1700	1285	5450		

EXHIBIT "D"

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A.A. GUN, M3 - CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES - (MED CAL); 4 per round. All assembling, measuring etc by GAUGE SECTION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ. IN.	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ. IN. (.015 MICR SPINDLE)	MEAN OF GAUGES WITH 0.0005" PISTON CL.	0.0010" PISTON CL.	COPPER OBTURATORS	WAX OBTURATORS	MEAN OF ALL GAUGES IN ROUND	INDIV MEAN DISPERSION PRESSURE	MAX DISPERSION GAUGES FIXED	MAX DISPERSION GAUGES LOOSE	INDIVIDUAL DISPERSION WITH 0.0005" PISTON CL.	0.0010" PISTON CL.	COPPER OBTURATORS	WAX OBT.	DATE OF FIRING	REMARKS
2	59	41,200	5942	38100	35215	40,400	42,950	32670	37,810	15,985		-7,990	-2,300	-250	+5,430		
3			4525	42700													
4		(H#1308 X1492 POWDER PYRO)	4734	42725													
5			4190	43200													
6	60		4970	42600	34,050	42,775	42,475	34,500	38,415	16,850		-7,950	-175	+475	+8,100	JAN. 30, 1936 P.M.	
7			2422	42950													
8			4748	426100													
9			2834	42000													
10	61		5908	41050	41,125	41,025	41,450	40,850	41,150		12,500	-7,950	+25	-450	+200		
11			3640	41000													
12			4744	40650													
13			4329	41900													
14	62		4774	33050	34,475	38,200	42,400	30,275	36,340	15,850		-6,925	-5,150	+450	+2,775		
15			1728	43350													
16			4875	27500													
17			3259	41450													
18	64	41,200	5942	39,200	29,600	41,300	40,450	30,450	35,450	21,700		-7,900	-2,100	+2,950	+8,750		
19			4525	43,400													
20			4734	21,700													
21			4190	37,500													
22	65		4970	42,350	24,950	41,600	35,850	32,700	34,275	19,300		-3,900	+750	+5,000	+9,650	JAN. 30, 1936 P.M.	
23			2422	40,850													
24			4748	23,050													
25			2834	30,850													
26	66		5908	42,950	40,785	42,600	42,875	41,515	42,200	4,175		-710	-650	+1,375	-1,435		
27			3640	44,250													
28			4744	40,075													
29			4329	41,500													
30	67		4774	32,500	31,250	33,325	35,675	28,900	32,290	11,900		-5,950	-825	+1,525	+3,600		
31			1728	34,150													
32			4875	25,500													
33			3259	37,200													
34																	
35				37,240	34,180	40,550	40,510	34,000	37,240	18,400	8,300	5260	1498	1622	4993		

EXHIBIT 'E'

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A.A. GUN NO. 3 CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (MEDICAL) 4 PER ROUND: ALL ASSEMBLIES, MEASURING ETC. BY GAUGE SECTION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SERIAL NO. OF ROUND	EXPECTED PRESSURE #/SQ. IN.	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ. IN. (0.75" MICR SPINDLE)	← MEAN OF GAUGES WITH 0.0005" PISTON CL.	0.0010" PISTON CL.	COPPER OBT. CUPS	WAX OBTURATOR	MEAN OF ALL GAUGES IN ROUND	INDIV. MEAN DISPERSION PRESSURE	MAX DISPERSION GAUGES FIXED	GAUGES LOOSE	0.0005" PISTON CL.	0.0010" PISTON CL.	COPPER OBT. CUPS	WAX OBT.	DATE OF FIRING	REMARKS
2	69	16.500	5942	16.900	17.000	16.875	15.900	16.340	+ 560	2.200					+1000		
3			4525	17.100					+ 760								
4		(2" - 140) X1492	4734	14.900					- 1440								
5			4190	16.450					+ 110								
6	70	PYRO POWDER	4970	17.950	17.900	15.825	15.825	15.740	+ 2.210	4.500					+2125		
7			2422	17.850					+ 2.110								
8			4748	13.700					- 2.040								
9			2834	13.450					- 2.290								
10	71		5908	17.575	17.540	17.225	17.225	16.640	+ 930	2.975					+350		
11			3640	17.500					+ 860								
12			4744	16.875					+ 235								
13			4329	16.600					- 2000								
14	72		4774	16.150	16.175	13.675	13.675	14.620	+ 1.530	5.000					+2475		
15			1728	16.200					+ 1.580								
16			4875	11.200					- 3.420								
17			3259	14.925					+ 305								
18	75	16.500	5942	17.300	17.225	16.050	16.050	16.300	+ 1000	2.350					+1.250		
19			4525	17.150					+ 850								
20			4734	14.800					- 1.500								
21			4190	15.950					- 350								
22	76		4970	18.700	18.590	14.715	16.715	15.745	+ 2.955	7.750					+1.925		
23			2422	18.475					+ 2.730								
24			4748	14.850					- .845								
25			2834	10.950					- 4.715								
26	77		5908	18.000	17.675	16.300	17.575	16.400	+ 1.060	2.750					+ 425		
27			3640	17.350					+ 410								
28			4744	17.150					+ 210								
29			4329	15.250					- 1.690								
30	78		4774	17.025	16.870	16.515	14.940	15.725	+ 1.300	4.175					+2.090		
31			1728	16.700					+ 975								
32			4875	12.850					- 2.875								
33			3259	14.325					+ 600								
34																	
35				16.050	14.640	17.370	16.000	16.000	16.000	4.200	3.725	11.40	111	12.35	2.690		

EXHIBIT "F"